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Middle Telychian (Llandovery, Silurian) graptolites and biostratigraphy of the Howgill Fells, England, based upon the collections of D.W.R. Wilson housed in the Lapworth Museum of Geology, University of Birmingham

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Abbreviated title: Middle Telychian graptolites, Howgills

Abstract: Examination of D.W.R. Wilson's PhD graptolite collection from the Howgill Fells, housed in the Lapworth Museum of Geology, University of Birmingham, reveals a high diversity (23 species) of middle Telychian graptolites from the uppermost *Streptograptus crispus* and *Streptograptus sartorius* (and possibly lowermost *Monoclimacis griestoniensis*) biozones. The collections include the first British records of *Pseudoplegmatograptus hexagonalis* and *Pristiograptus pergratus*. The stratigraphical range of *P. pristinus* is extended upwards, into the *sartorius* Biozone. One specimen of *Stimulograptus clintonensis* shows remarkable dorsal rhabdosome curvature proximally. *Torquigraptus* is particularly diverse in the *sartorius* Biozone with at least six species present: one new species, *T. wilsoni*, is described and two probable new species, one of which is very similar to the lower Telychian *T. cavei*, are left in open nomenclature.

The graptolites of the Howgill Fells of Cumbria have been the subject of numerous published stratigraphical and taxonomic studies (e.g. Rickards 1965, 1967, 1970, 1973; Rickards & Woodcock 2005). Those from the middle Telychian (upper Llandovery), however, have received much less attention, largely because Rickards' PhD thesis work (which formed the basis of his earlier publications) focused much less on the part of the Howgills succession that had been studied in detail by D.W.R. Wilson (1954) during his PhD research. Fortunately, some of Wilson's collections remain in the Lapworth Museum of Geology's collections at the University of Birmingham (specimen numbers prefixed BIRUG: BU) and these form the basis of this paper.

Wilson (1954) measured and described seven sections in considerable detail, with records of individual beds down to ⅛" (c. 3mm) thick. Wilson's graptolite collections from five of these localities (shown in Fig. 1) were available for study. Very usefully, he had painted locality and horizon numbers onto the graptolite-bearing slabs and these are cross-referenced in the Appendix to his thesis. The available material (52 graptolitic slabs) is from the highest bed within the *Streptograptus crispus* Biozone and from six of the seven graptolitic horizons above the last appearance of *Streptograptus crispus*. Wilson (1954) referred to his sections by letter (a–g) and the same lettering system is used in the text below, in Figure 1 and the figure captions to Figures 3–6. Detailed locality maps and descriptions of the sections are present in Wilson's thesis, to which the reader is referred. The five sections from which graptolite collections have been studied for the present paper are: (a) Hebblethwaite Hall Gill (from National Grid Reference SD 6881 9293 to SD 6910 9318); (b) Rawthey – Birksfield Beck, SD 6913 9493 to SD 6916 9510; (c) Rawthey – Wards Intake, SD 7160 9732 to SD 7165 9739; (d) Rawthey – Mouth of Wandale Beck, SD 7074 9775 to SD 7085 9780; and (e) Wandale

Hill, section starting at SD 7045 9795. Of these, Hebblethwaite Hall Gill was considered to be 'the best [section] in the district from the point of view of the present work' such that 'a full sequence from the *turriculatus*-zone to the base of the Wenlock can be measured.'

Fourteen graptolitic horizons (labelled in ascending stratigraphical order F14–F1), commencing in the *crispus* Biozone and extending over a stratigraphical thickness of 16'11" (5.15 m), were identified in Hebblethwaite Hall Gill (Fig. 2). Some of these had distinctive lithological characteristics (e.g. interbedded volcanic material) and most were identifiable in all of the other sections studied, although Wilson noted that Beds F4, F2 and F1 were not developed in sections (d) and (e) which had a much lesser stratigraphical thickness, approximately half that of (a). This he attributed to the existence a submarine ridge in the area of (d) and (e) at the time of deposition (see also Rickards 1989, fig. 89). As can be seen from Figure 2, less than 15% of the thickness of strata exposed in the Hebblethwaite Hall Gill section is graptolitic, a typical feature of British Telychian sections (Zalasiewicz 1990, fig. 1), with interbedded strata being bioturbated mudstones deposited under oxic bottom water conditions and volcanic deposits (including numerous bentonites).

Graptolite biostratigraphy

The stratigraphical occurrences of Wilson's graptolites are shown on Figure 2 with all species illustrated in Figures 3–6. In the captions for these the F horizon and section from which the graptolites were collected is indicated. A list of species identified from each locality and horizon is provided in the Appendix.

As long as the highly distinctive *Streptograptus crispus* (Lapworth, 1876) is present, recognising the *crispus* Biozone is very straightforward and Wilson (1954) was able to place the lower seven of his graptolitic F horizons (F14–F8) confidently in this biozone. Above the last appearance of *S. crispus*, however, assigning graptolitic strata to a biozone becomes more challenging. The traditional Telychian biozonation had the *crispus* Biozone succeeded by the *Monoclimacis griestoniensis* Biozone (see e.g. Rickards 1976), but in the Howgills, as in Wales (Zalasiewicz 1994) and Estonia (Loydell *et al.* 1998), there is an interval between these biozones that lacks both *S. crispus* and *Mcl. griestoniensis* (Nicol, 1850). Zalasiewicz (1994) referred this to the *Streptograptus sartorius* Subzone (as the uppermost subzone of the *crispus* Biozone), but it was subsequently afforded biozonal status (e.g. Loydell *et al.* 1998; Zalasiewicz *et al.* 2009) on the basis that it represents strata deposited after the last appearance of *S. crispus*.

Wilson (1954) recorded *S. sartorius* from horizons F4 and F3 only and it seems reasonable to assign these two horizons to the *sartorius* Biozone. This leaves horizons F7–F5 unzoned; Wilson recorded only long-ranging taxa from them. *Monoclimacis griestoniensis* is not present in any of the post-*crispus* graptolitic horizons in the Howgills. *Monoclimacis directa* Zalasiewicz, Loydell & Štorch, 1995, however, occurs from horizons F4 to F1. In Wales its first appearance precedes that of *Mcl. griestoniensis* (Zalasiewicz 1990), but its range extends into the lower part of the *griestoniensis* Biozone in which the biozonal index is rare and *Mcl. directa* is common. In the Ohesaare core, Estonia (Loydell *et al.* 1998) a single sample (from 370.70 m) yielded *Mcl. directa*, *S. sartorius* and *Spirograptus turriculatus* (Barrande, 1850) (the last has never been recorded from the *griestoniensis* Biozone), with the succeeding sample (from 370.45–370.50 m) containing a lower *griestoniensis* Biozone assemblage, including the biozonal index. It is clear therefore that the stratigraphical range of *Mcl. directa* is from the *sartorius* Biozone to a level within the *griestoniensis* Biozone, but whether the highest Howgills graptolitic horizons represent the upper *sartorius* or lower *griestoniensis*

Biozone is impossible to determine. The only other short-ranging species appearing within this interval is *Torquigraptus pragensis* (Přibyl, 1943), but this has a similar stratigraphical distribution to *S. sartorius* (i.e. *sartorius* to lower *griestoniensis* Biozone) so, unfortunately, its presence in F3, F2 and F1 does not resolve the issue. A conservative approach is adopted in Figure 2, with F14–F8 assigned to the *crispus* Biozone, F7–F5 left unzoned, F4 and F3 assigned to the *sartorius* Biozone and F2 and F1 to this biozone or the lower *griestoniensis* Biozone.

Notes on graptolite species

Biserials

Glyptograptus is represented by the diminutive *G. nebula* Toghill & Strachan, 1970 (Figs 3A, F), originally described from the *griestoniensis* Biozone, and subsequently (e.g. by Hutt 1974) from lower in the Telychian (*turriculatus* and *crispus* biozones). Toghill & Strachan (1970, p. 519) referred to the 'thin 'ghost-like' periderm' of the species which results in a clearly seen sicula and nema and these are seen in the flattened Howgills specimens (e.g. Fig. 3A). Toghill & Strachan (1970) quoted a maximum rhabdosome width of 0.6 mm; some of Hutt's specimens had a greater width (0.75 mm) and this is attained also by one of the Howgills specimens (Fig. 3F).

Wilson (1954) recognised that the distinctive features of the *Petalograptus* (now *Parapetalolithus*) material that he had were sufficient 'to justify its erection as a new variety or species.' Hutt (1974) encountered similar specimens in the Lake District and erected *Petalograptus* (now *Parapetalolithus*) *wilsoni*. One feature of the species is the twisted and expanded vane-like nematularium. A remarkable specimen in Wilson's collection (Fig. 3J) shows the growth of distal thecae around the nematularium and the thickening around the margins of the structure.

The most conspicuous of the retiolitids present is *Retiolites angustidens* Elles & Wood, 1908 (Fig. 3B). The other identifiable retiolitid specimens are assigned to *Pseudoplegmatograptus hexagonalis* (Bouček and Münch, 1944), which, as its name suggests, possesses a reticulum largely formed of hexagons (Fig. 3H). This is the first British record of this species. The more frequently recorded *Pseudoplegmatograptus obesus* (Lapworth, 1877) differs in having a more irregular reticular meshwork. *Pseudoplegmatograptus elleswoodae* (Bouček and Münch, 1944), first illustrated by Elles & Wood (1908, text-fig. 224, pl. 34, fig. 13a, b), also possesses a hexagonal meshwork, but the individual hexagons are much larger than in *Pse. hexagonalis*.

Uniserials

The species of *Streptograptus* present include the two biozonal indices, *S. crispus* (Lapworth, 1876)(Fig. 3O) and *S. sartorius* (Törnquist, 1881)(Figs 3I, 4E). Both are well known (see e.g. Zalasiewicz 1994) and in the case of the latter, described also from superbly preserved chemically isolated material (Loydell & Maletz 2004). Also in the collections are the ventrally (fish-hook) curved species, *S. exiguus* (Lapworth, 1876)(Fig. 3K) and the similar, but broader, *S. loydelli* Štorch & Serpagli, 1993 (Fig. 4C). The latter is subzonal index for the upper *crispus* Biozone (Zalasiewicz *et al.* 2009), but ranges into the *griestoniensis* Biozone from which it was originally described.

Three species of *Pristiograptus* are present. A proximal end of *P. bjerringus* (Bjerreskov, 1975)(Fig. 3L) shows this species' characteristic rapid increase in dorso-ventral width. Originally described from the *turriculatus* Biozone, the stratigraphical range of this species has been extended recently into the *crispus* Biozone (Walasek *et al.* 2018) and it is from this biozone that the Howgills specimen originates. Most of Wilson's specimens of *Pristiograptus* belong to *P. pristinus* Přibyl, 1940 (Fig. 3M, N). This is a long-ranging species, first appearing in the upper Aeronian (Loydell 1993). The Howgills specimens represent the stratigraphically youngest record, extending the top of the species' range from the *turriculatus* Biozone to the *sartorius* Biozone. Another species recorded from Britain for the first time is *P. pergratus* Přibyl, 1940 (Fig. 3C), which matches very closely the type material of this species from the *crispus* Biozone of the Czech Republic. The single Howgills specimen is from the highest graptolite band (F1). This apparently rare species has also been recorded from the *crispus*–lower *griestoniensis* biozones of Latvia (Loydell *et al.* 2003).

Two well-known species of *Monograptus* are present: *M. marri* Perner, 1897 (Fig. 3D) and the more rapidly widening *M. priodon* (Bronn, 1835) (Fig. 4F). Although in Britain the stratigraphically highest confidently identified *M. marri* is stated to be from the *turriculatus* Biozone by Zalasiewicz *et al.* (2009), Rickards (1976) had recorded the species in Britain from as high as the *griestoniensis* Biozone, and Loydell *et al.* (1998) recorded and illustrated a specimen from the lower part of the *griestoniensis* Biozone of the Ohesaare core, Estonia. *Stimulograptus* is, as is typical of mid Telychian assemblages, represented by *St. clintonensis* (Hall, 1852) (Figs 4H, J, 5D), distinguishable from *M. marri* (and other species of *Monograptus*) by its non-overlapping thecae. Normally rhabdosomes of this species are straight or very nearly so, but two specimens on the same bedding plane from F3 show proximal dorsal curvature of an extent not previously recorded. In one specimen (Fig. 4J) there are 90° of dorsal curvature (from th1–11) before the rhabdosome becomes straight; in the other (Fig. 4H) the curvature is less pronounced and affects fewer thecae (th1–8). Thecal morphology, rhabdosome dorso-ventral width and thecal spacing are as seen in 'normal' specimens of *St. clintonensis* and these specimens are assigned to this species but considered (particularly Fig. 4J) at the extremity of intraspecific variation.

Wilson (1954) recognised that his specimens of *Monoclimacis* (e.g. Fig. 3G) from the higher graptolitic beds in his sections were intermediate in width between *Mcl. griestoniensis* (Nicol, 1850) and *Mcl. crenulata* (Elles & Wood, 1911). Zalasiewicz *et al.* (1995) revised a number of Telychian *Monoclimacis* species and erected a new species, *Mcl. directa*, for this species. It has been recorded also from central Wales (Zalasiewicz 1994), Estonia (Loydell *et al.* 1998) and Australia (Rickards and Jell 2002).

With the exception of the highly distinctive *T. pragensis* (Přibyl, 1943) (Figs 4I, 5B), the most challenging uniserial Telychian graptolites to identify are those belonging to *Torquigraptus*. In part, this is because there have been only a few detailed studies (e.g. Zalasiewicz 1994; Štorch 1998). There are also the problems that (1) many *Torquigraptus* species exhibit a considerable amount of intraspecific variation (see e.g. *T. tullbergi* in Štorch 1998 and *T. obtusus* in Loydell *et al.* 2015); (2) torsion of the rhabdosome axis can result in thecal details being obscured or unusually distorted or accentuated upon diagenetic flattening; and (3) there are strong similarities between a number of species. As a result it is frequently not possible to identify fragmentary specimens to species level.

Torquigraptus australis Štorch, 1998 is represented by a single specimen (Fig. 5A) showing the gradual increase in dorso-ventral width along the gently dorsally curved proximal part of the rhabdosome and distal spiralling. Similarly, there is only a single specimen, a proximal end (Fig. 4G), of *Torquigraptus proteus* (Barrande, 1850), a species that first appears in the *turriculatus* Biozone, but which occurs also in higher biozones, e.g. in the *crispus*–*griestoniensis* biozones in Bohemia (Štorch 1994). The Howgills specimen matches very closely material from the species' type locality, Litohlavy in Bohemia. A distinctive new species, *T. wilsoni*, is described below.

Torquigraptus cavei Loydell, 1993 is a species recorded from the lower Telychian (upper *guerichi* and lowermost *turriculatus* biozones). A remarkably similar species (Figs 4B, 5C, F) occurs in horizon F3 at three Howgills localities ((b), (c) and (e)). None of the specimens possesses a proximal end so it is uncertain how long the narrow proximal part of the rhabdosome is, but all show the rapid increase in dorso-ventral width at the point where rhabdosome curvature becomes more pronounced that is typical of *T. cavei*; measurements (dorso-ventral width and thecal spacing) also are similar. The main difference between these Howgill specimens and *T. cavei* is the narrower bases to the thecae in the region of maximum rhabdosome curvature. They are assigned here to *T.* aff. *cavei*, a reflection of their similarity to but not conspecificity with this earlier Telychian species. This is a good example of iterative evolution and emphasizes that considerable caution should be adopted when identifying *Torquigraptus* species and using them biostratigraphically. Finally, a single specimen (Fig. 4D), again from horizon F3, resembles *T. spiraloides* (Přibyl, 1945) in rhabdosome and thecal morphology, but is narrower (maximum dorso-ventral width of figured specimen is 1.05 mm at a level within the rhabdosome at which it would be 1.4 mm in *T. spiraloides*). It is referred here to *T.* aff. *spiraloides*. There are therefore at least six species of *Torquigraptus* within the *sartorius* Biozone of the Howgills.

In addition to these various *Torquigraptus* species, Wilson's collection includes specimens of another strongly dorsally curved uniserial graptolite, assigned by Zalasiewicz (1994) to *Monograptus* (presumably *sensu lato*). Zalasiewicz's material of '*M.*' *pseudocommunis* comprised three-dimensional internal moulds with apparently fairly simple, hooked, symmetrical thecal apertures. The flattened Howgills specimens (Fig. 4A, 5E) suggest greater thecal apertural complexity but confident assignment to a genus probably must await examination of chemically isolated material. Zalasiewicz (1994) had limited material (eight specimens) of his new species, and with all specimens being proximal ends/fragments, the rhabdosome was described as 'short'. Most of the Howgill specimens are proximal ends, very similar to the type material (e.g. Fig. 4A). There are also, however, much more fully developed rhabdosomes (Fig. 5E) that exhibit both torsion of the rhabdosome axis and that the overall rhabdosome morphology is much less similar to that of *Campograptus communis* (Lapworth, 1876), to which '*M.*' *pseudocommunis* was originally compared (Zalasiewicz 1994), resembling much more that of *Oktavites*.

Systematic Palaeontology

Genus **Torquigraptus** Loydell, 1993

Torquigraptus wilsoni sp. nov. (Fig. 6A–F)

Holotype. BIRUG: BU5638 (Fig. 6F), from Horizon F3, *Streptograptus sartorius* Biozone, Rawthey – Wards Intake section, Howgill Fells.

Material. Seven specimens, all from Horizon F3, *Streptograptus sartorius* Biozone: six from the Rawthey – Wards Intake section and one from Wandale Hill. All are flattened.

Derivation of name. After the collector of the material, D.W.R. Wilson.

Diagnosis. Torquigraptus with rhabdosome forming a low initially dorsally curved helical spiral exhibiting sharp torsion of the rhabdosome axis above th5 or th6.

Description. Rhabdosomes comprise between one and one-and-a-half whorls of what appears originally to have been a low helical spiral. Dorsal curvature is maintained proximally despite the rhabdosome axis twisting sharply above th5 or th6. Further torsion of the rhabdosome axis results in thecal details being obscured. Parts of the narrow sicula are visible in three specimens, but in none is it well enough preserved for accurate measurement of its length. Thecae are triangular throughout, being axially elongated proximally. The thecal aperture is twisted to the reverse side of the rhabdosome. Theca 1 is not well enough preserved to be measured, but dorso-ventral width (DVW) thereafter increases rapidly: it is 0.35 mm at th2, 0.4 mm at th3 and 0.7 mm at th5. The maximum DVW at th13 or th14 is slightly in excess of 1.0 mm. 2TRD decreases from 1.8 mm at th3 to 1.45–1.7 mm in thecae distal to the point of rhabdosome torsion (i.e. distal to th5 or th6).

Remarks. The rhabdosome morphology proximally is reminiscent of that of some specimens of *Oktavites contortus* (Perner, 1897), a species known from the upper Aeronian and lower Telychian. That species, however, has more complex, laterally expanded thecae (Hutt *et al.* 1970; Loydell & Zhao 1990) and a more tightly spirally curved rhabdosome (e.g. Loydell *et al.* 2015, fig. 19D). There are no similar species of *Torquigraptus*.

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Appendix Listed here are localities, fossiliferous horizons and the fossils identified from these. Biserial graptolites are listed first, followed by uniserial graptolites, in alphabetical order, followed by other fossils.

a) Hebblethwaite Hall Gill

F6: *Parapetalolithus wilsoni*, *Cochlograptus veles*, *Monograptus marri*

(b) Rawthey – Birksfield Beck

F3: *Monoclimacis directa*, *Monograptus marri*, *M. priodon*, '*M.*' *pseudocommunis*, *Stimulograptus clintonensis*, *Streptograptus sartorius*, *Torquigraptus* aff. *cavei*

(c) Rawthey – Wards Intake.

F1: *Glyptograptus nebula*, *Retiolites angustidens*, *Monoclimacis directa*, *Pristiograptus pergratus*, *Streptograptus exiguus*, *S. loydelli*, *Torquigraptus pragensis*

F2: *Monoclimacis directa*, *Stimulograptus clintonensis*, *Torquigraptus pragensis*

F3: *Pseudoplegmatograptus hexagonalis*, *Monoclimacis directa*, *Monograptus marri*, *M. priodon*, '*M.*' *pseudocommunis*, *Pristiograptus pristinus*, *Streptograptus sartorius*, *Stimulograptus clintonensis*, *Torquigraptus australis*, *T.* aff. *cavei*, *T. pragensis*, *T.* aff. *spiraloides*, *T. wilsoni* sp. nov., conodont

F4: *Monoclimacis directa*, *Monograptus priodon*, *Streptograptus sartorius*, *Torquigraptus proteus*

F7: *Parapetalolithus wilsoni*, *Monograptus priodon*, *Pristiograptus pristinus*, *Torquigraptus* sp. indet.

F8: *Glyptograptus nebula*, *Pseudoplegmatograptus hexagonalis*, *Pristiograptus bjerringus*, *Stimulograptus clintonensis*, *Streptograptus loydelli*

(d) Rawthey – Mouth of Wandale Beck

F3: *Parapetalolithus wilsoni*, *Monoclimacis directa*, *Pristiograptus pristinus*?, *Stimulograptus clintonensis*, *Streptograptus sartorius*

F8: *Glyptograptus nebula*, *Cochlograptus veles*, *Monograptus* sp. indet., *Stimulograptus clintonensis*, *Streptograptus crispus*, *S. loydelli*, *Aptychopsis*

(e) Wandale Hill

F3: *Pseudoplegmatograptus hexagonalis*, *Monoclimacis directa*, *Monograptus marri*, *M. priodon*, '*M.*' *pseudocommunis*, *Pristiograptus pristinus*, *Streptograptus sartorius*, *Stimulograptus clintonensis*, *Torquigraptus* aff. *cavei*, *T. wilsoni*

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Fig. 1. Graptolitic middle Telychian localities referred to in the text plotted on part of Rickards' (1967, pl. 12) geological map of the eastern Howgill Fells. Lithostratigraphy has been updated and is that used in Rickards & Woodcock (2005). Sections are referred to using the locality names of Wilson (1954): (**a**) Hebblethwaite Hall Gill (from National Grid Reference SD 6881 9293 to SD 6910 9318); (**b**) Rawthey – Birksfield Beck, SD 6913 9493 to SD 6916 9510; (**c**) Rawthey – Wards Intake, SD 7160 9732 to SD 7165 9739; (**d**) Rawthey – Mouth of Wandale Beck, SD 7074 9775 to SD 7085 9780; and (**e**) Wandale Hill, section starting at SD 7045 9795.

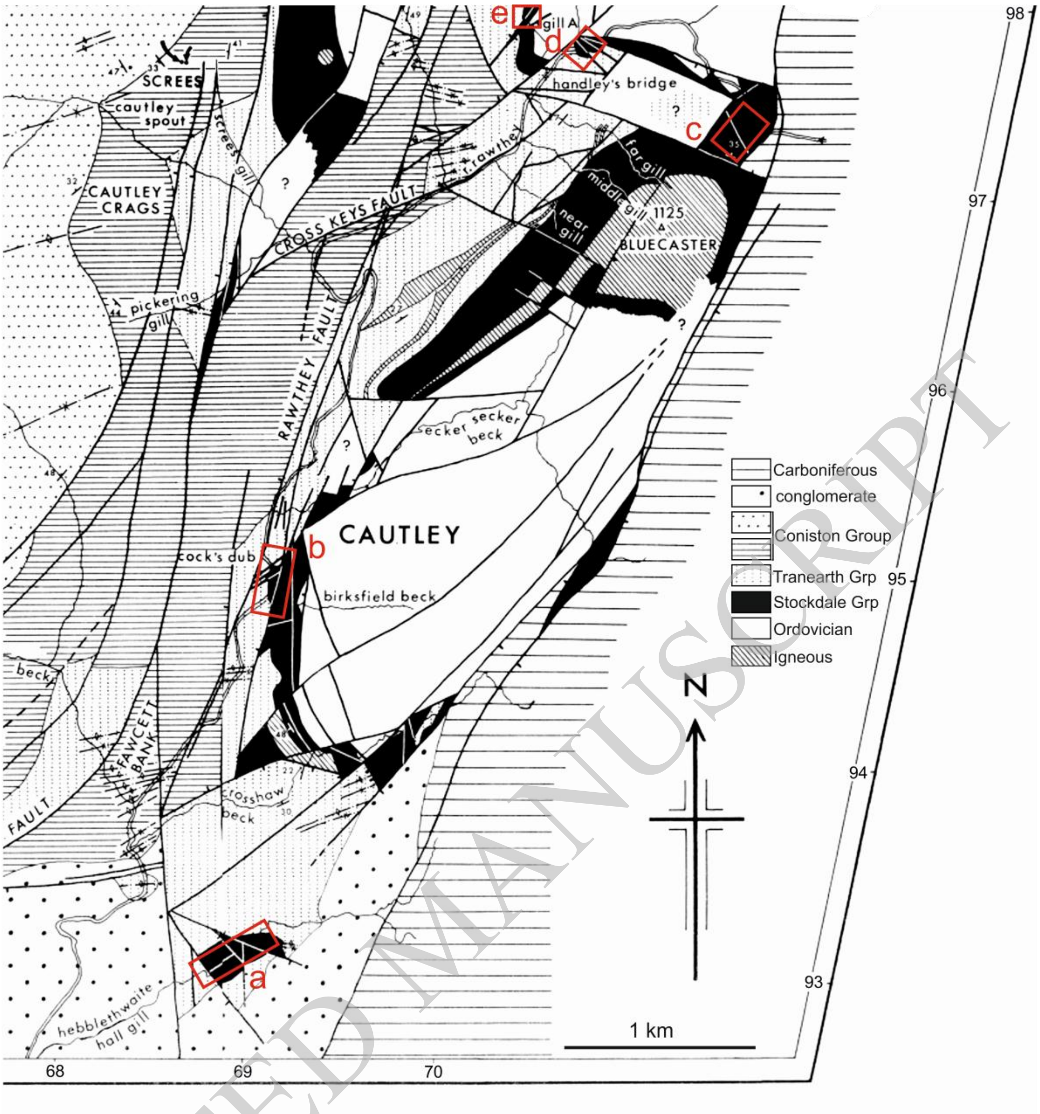
Fig. 2. Graptolitic horizons in the middle Telychian of the Hebblethwaite Hall Gill section (modified from Wilson 1954). Plotted also are the occurrences of graptolites from all five Howgill sections from what remains of Wilson's PhD collection, housed in the Lapworth Museum of Geology's collections at the University of Birmingham.

Fig. 3. Graptolites from the middle Telychian of the Howgill Fells. Scale bar represents 10 mm. A, F, *Glyptograptus nebula* Toghill & Strachan, 1970, F8; A, BIRUG: BU5601, flattened specimen showing thin periderm, section (c); F, BIRUG: BU5606, section (d). B, BIRUG: BU5602, *Retiolites angustidens* Elles & Wood, 1908, distal fragment, F1, section (c). C, *Pristiograptus pergratus* Přibyl, 1940, BIRUG: BU5603, F1, section (c). D, *Monograptus marri* Perner, 1897, BIRUG: BU5604, F6, section (a). E, *Cochlograptus veles* (Richter, 1871), BIRUG: BU5605, F8, section (d). G, *Monoclimacis directa* Zalasiewicz, Loydell & Štorch, 1995, BIRUG: BU5607, F3, section (c). H, *Pseudoplegmatograptus hexagonalis* (Bouček and Münch, 1944), BIRUG: BU5608, F3, section (e). I, *Streptograptus sartorius* (Törnquist, 1881), BIRUG: BU5609, three-dimensionally preserved, F3, section (e). J, *Parapetalolithus wilsoni* (Hutt, 1974), BIRUG: BU5610, F7, section (c). K, *Streptograptus exiguus* (Lapworth, 1876), BIRUG: BU5611, F1, section (c). L, *Pristiograptus bjerringus* (Bjerreskov, 1975), BIRUG: BU5612, F8, section (c). M, N, *Pristiograptus pristinus* Přibyl, 1940, section (c); M, BIRUG: BU5613, F7; N, BIRUG: BU5614, F3. O, *Streptograptus crispus* (Lapworth, 1876); F8, BIRUG: BU5615, section (d).

Fig. 4. Graptolites from the middle Telychian of the Howgill Fells, section (c). Scale bar represents 10 mm. A, '*Monograptus*' *pseudocommunis* Zalasiewicz, 1994, BIRUG: BU5616, F3. B, *Torquigraptus* aff. *cavei* Loydell, 1993, BIRUG: BU5617, F3. C, *Streptograptus loydelli* Štorch & Serpagli, 1993, BIRUG: BU5618, F1. D, *Torquigraptus* aff. *spiraloides* (Přibyl, 1945), BIRUG: BU5619, F3. E, *Streptograptus sartorius* (Törnquist, 1881), BIRUG: BU5620, F3. F, *Monograptus priodon* (Bronn, 1835), BIRUG: BU5621, F7. G, *Torquigraptus proteus* (Barrande, 1850), BIRUG: BU5622, F4. H, J, *Stimulograptus clintonensis* (Hall, 1852), F3; H, BIRUG: BU5623; J, BIRUG: BU5625, specimen showing remarkable proximal dorsal rhabdosome curvature. I, *Torquigraptus pragensis* (Přibyl, 1943), BIRUG: BU5624, F1.

Fig. 5. Graptolites from the middle Telychian of the Howgill Fells. Scale bar represents 10 mm. A, *Torquigraptus australis* Štorch, 1998, BIRUG: BU5626, F3, section (c). B, *Torquigraptus pragensis* (Přibyl, 1943), BIRUG: BU5627, F2, section (c). C, F, *Torquigraptus* aff. *cavei* Loydell, 1993, F3; C, BIRUG: BU5628, section (c); F, BIRUG: BU5631, section (e). D, *Stimulograptus clintonensis* (Hall, 1852), BIRUG: BU5629, distal thecae, F3, section (e). E, '*Monograptus*' *pseudocommunis* Zalasiewicz, 1994, BIRUG: BU5630, F3, section (c).

Fig. 6. *Torquigraptus wilsoni* sp. nov., F3, all except D are from section (c). Scale bar represents 10 mm. A, BIRUG: BU5632; B, BIRUG: BU5633 and BU5634; C, BIRUG: BU5635; D, BIRUG: BU5636, section (e); E, BIRUG: BU5637; F, BIRUG: BU5638, holotype.



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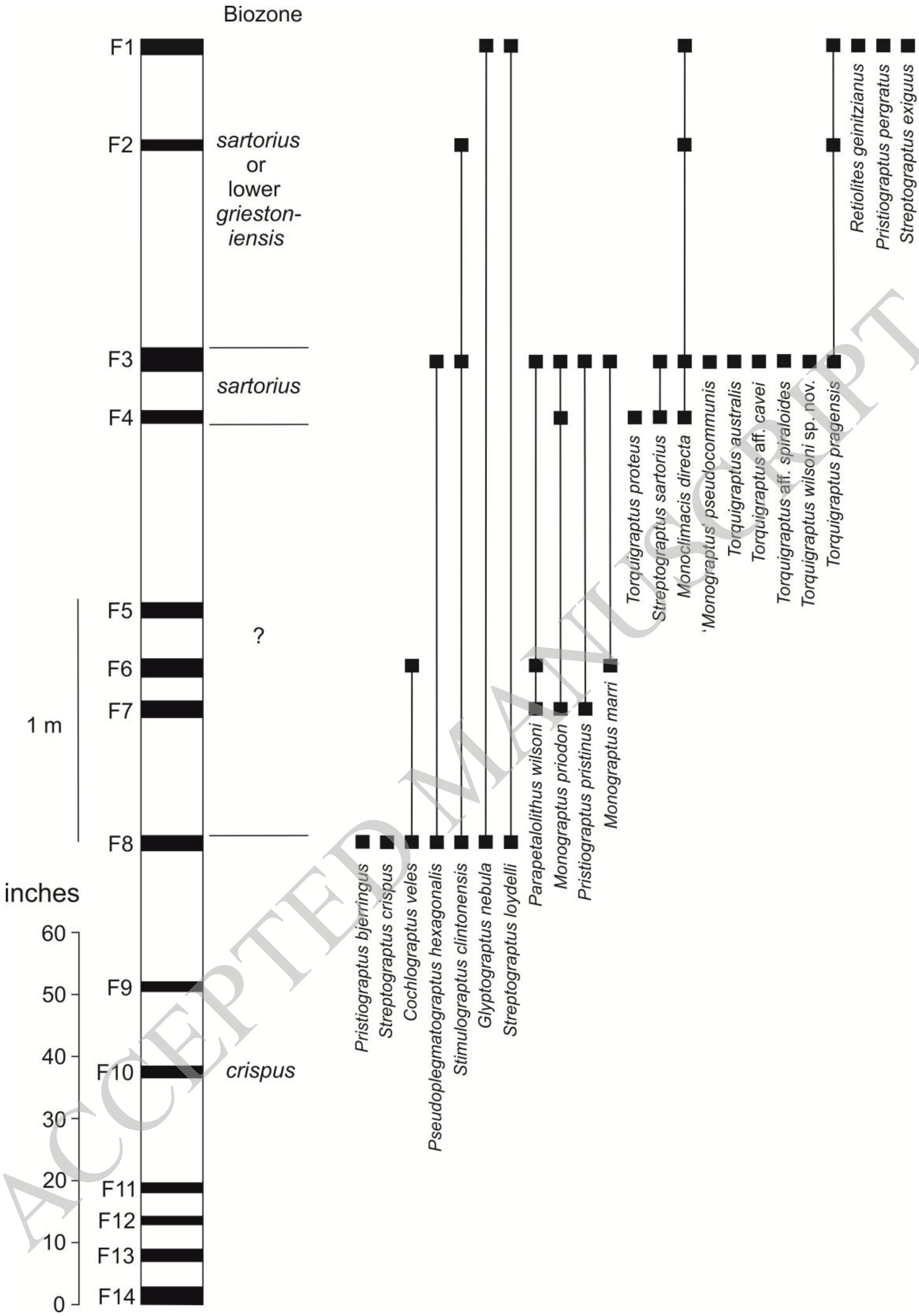
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Streptograptus sartorius
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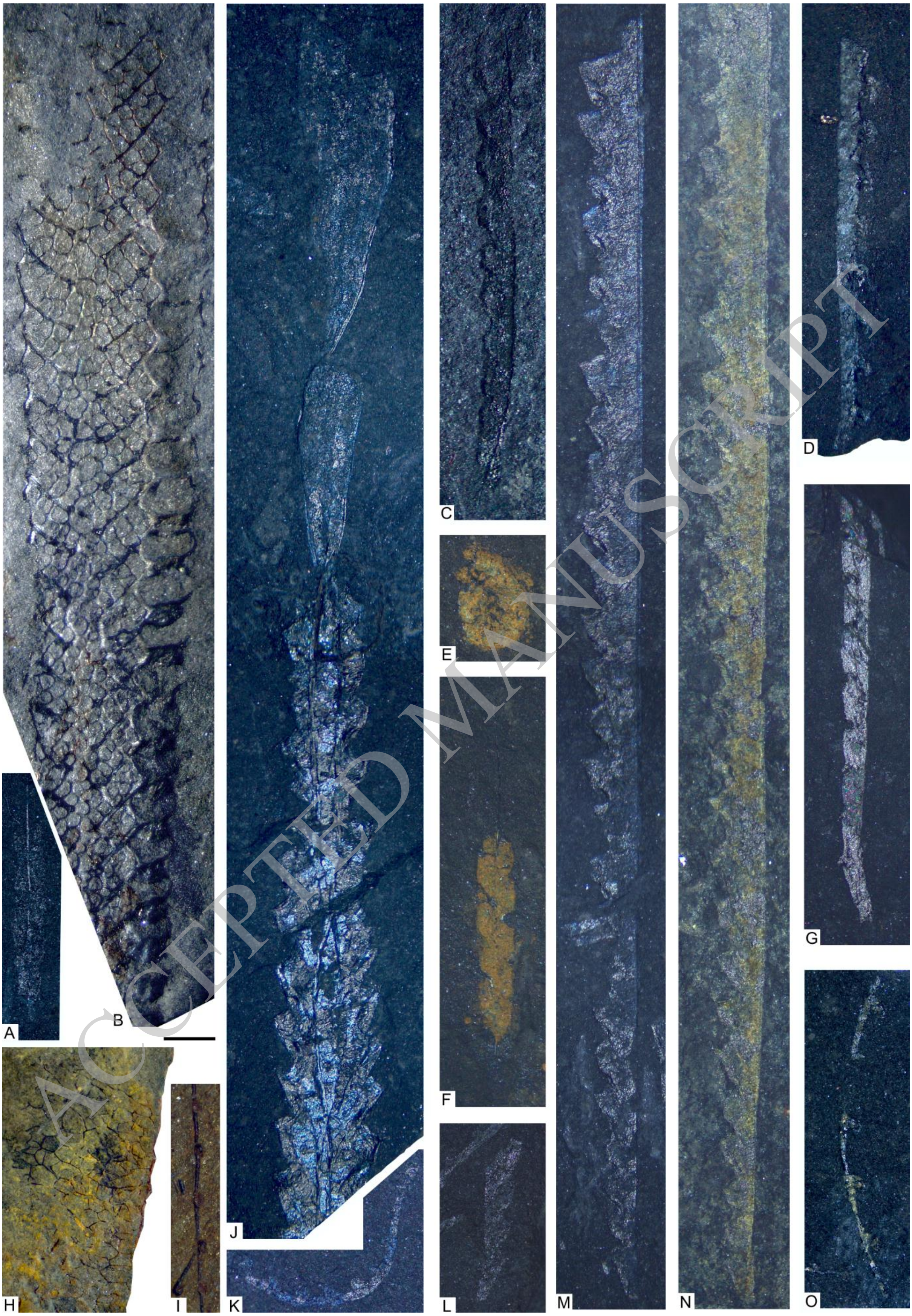
Pristiograptus pergratus
Streptograptus exiguus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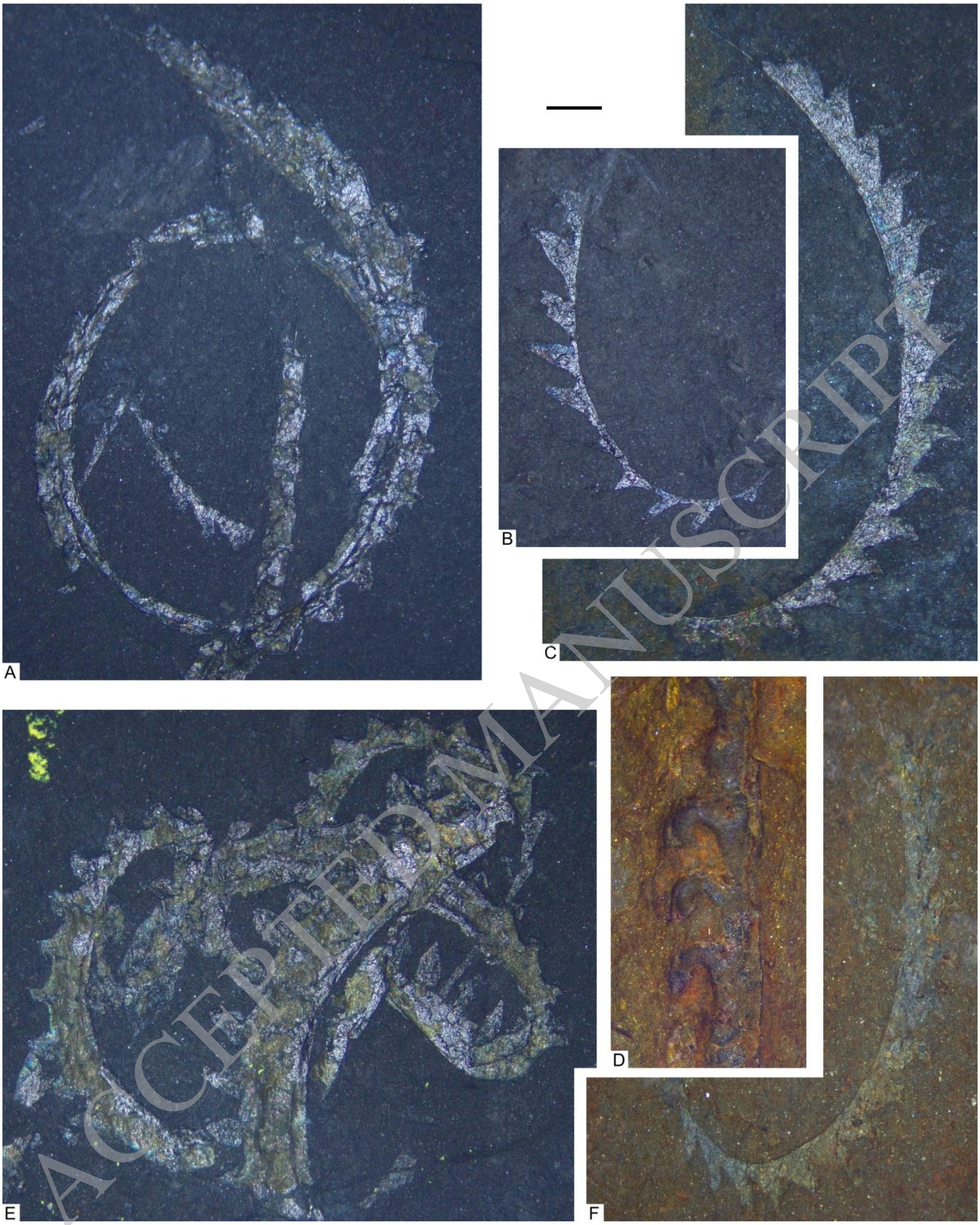
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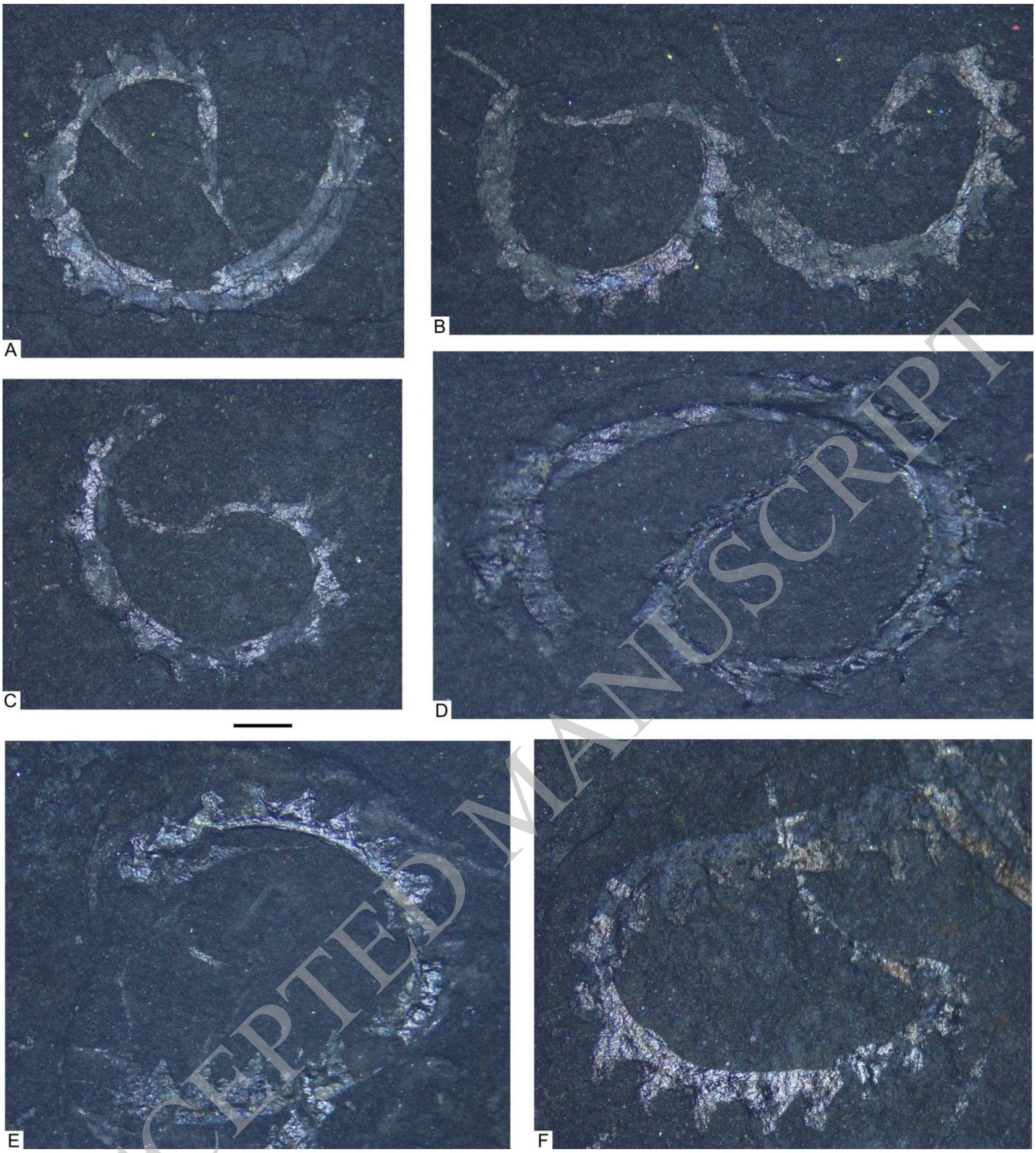
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